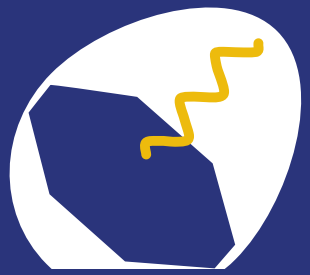


MAGIC

Major Atmospheric Gamma Imaging Cerenkov Telescopes

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

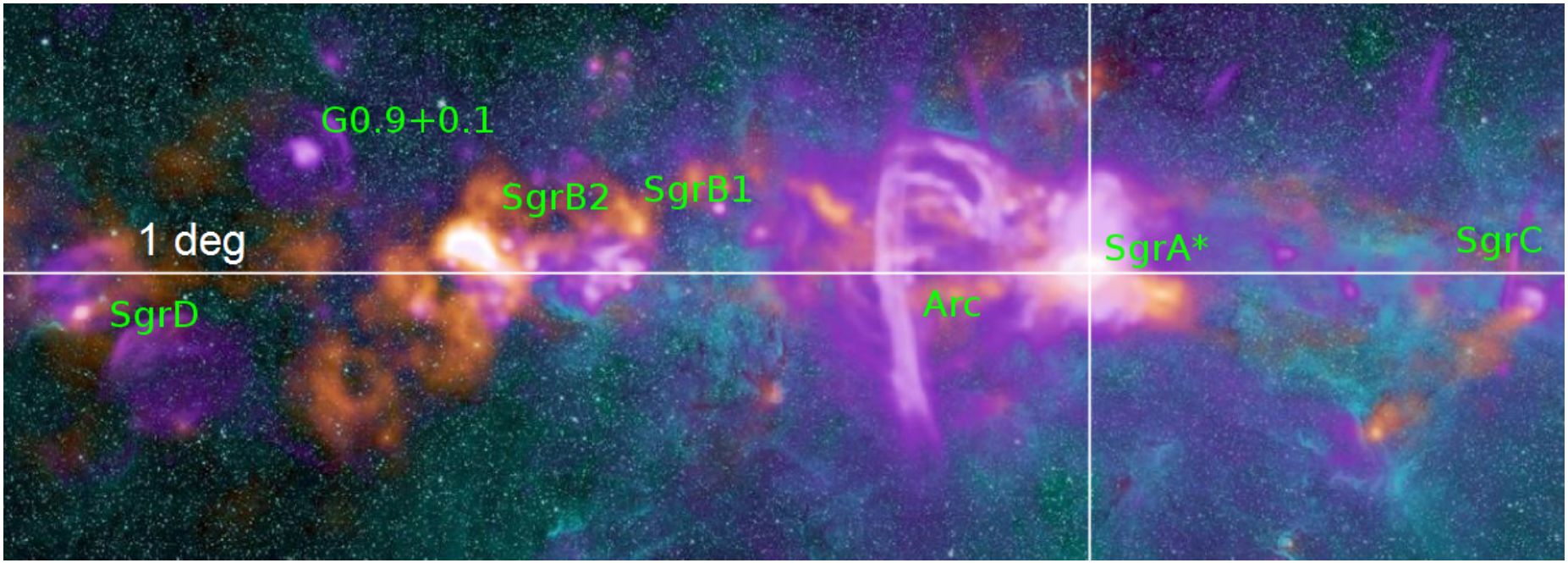
MAX-PLANCK-GESELLSCHAFT

Spectral, morphological and temporal analysis of the Galactic Center gamma-ray emission based on new observations with MAGIC

Christian Fruck for the MAGIC Collaboration
fruck@mpp.mpg.de

DPG Frühjahrstagung - Hamburg - March 2016

The Galactic Center: in 20cm, 1.1mm, IR



- GC hosts Super Massive Black Hole (SMBH) $(4 \cdot 10^6\,\mathrm{M}_\odot)$
- very dense and active astrophysical environment
- considered good place to search for DM annihilation/decay

image source: http://images.nrao.edu

G2 gas cloud falling onto the Galactic Center

- report about a gas cloud of three times the Earth mass on its way to SgrA* (S. Gillessen et al. 2012)
- pericenter passage 2013-2014, $\approx$ 2000 Schwarzschild radii (S. Gillessen et al. 2013) ($\approx$ 25 light hours or 20$\times$ Saturns semi major axis)
- possible that part of the cloud interacts with the SMBH

$\Rightarrow$ monitoring campaigns triggered in nearly all wavelengths (radio to γ rays)

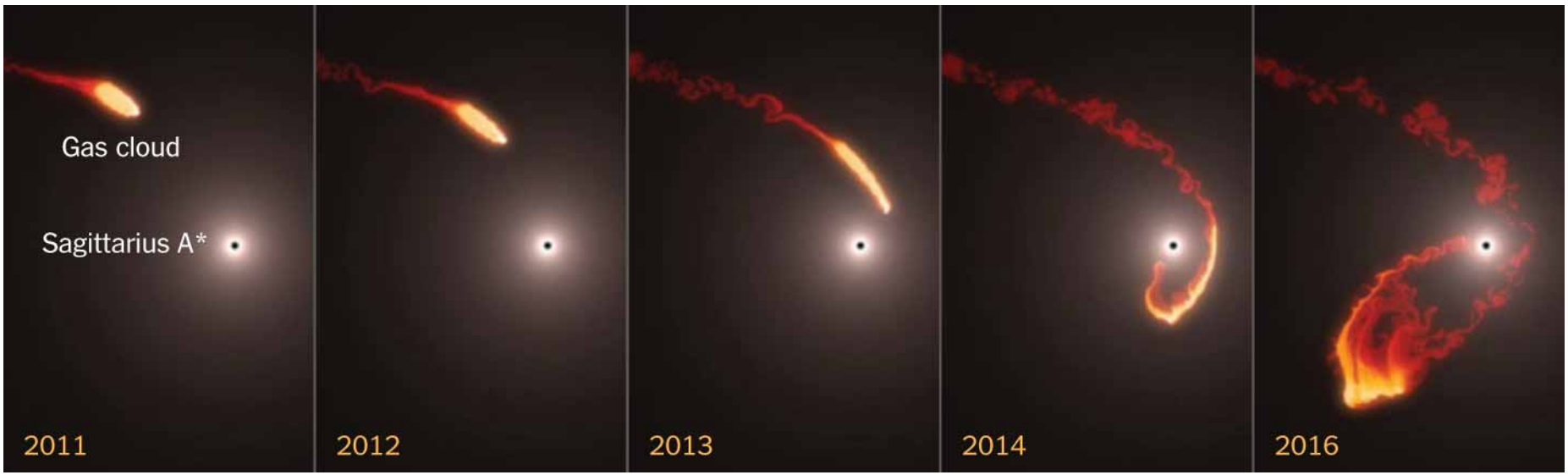


image source: ESO

Possible observable effects in an interaction scenario:

- Formation of a hot accretion disk
  - $\Rightarrow$ Production of thermal X-rays (X-ray satellites)
- Production of energetic electrons (in shock/jet/magnetosphere)
  - $\Rightarrow$ Synchrotron radiation from Radio to X-ray from energetic electrons (Radio telescopes, X-ray satellites)
  - $\Rightarrow$ Bremsstrahlung and/or Inverse Compton scattering of high energy e^- (γ ray satellite observatories, ground based γ ray observatories)
- Acceleration of protons and heavy nuclei (shock/jet/magnetosphere)
  - $\Rightarrow$ π^0 production in interaction of hadronic cosmic rays (γ ray satellite observatories, ground based γ ray observatories)

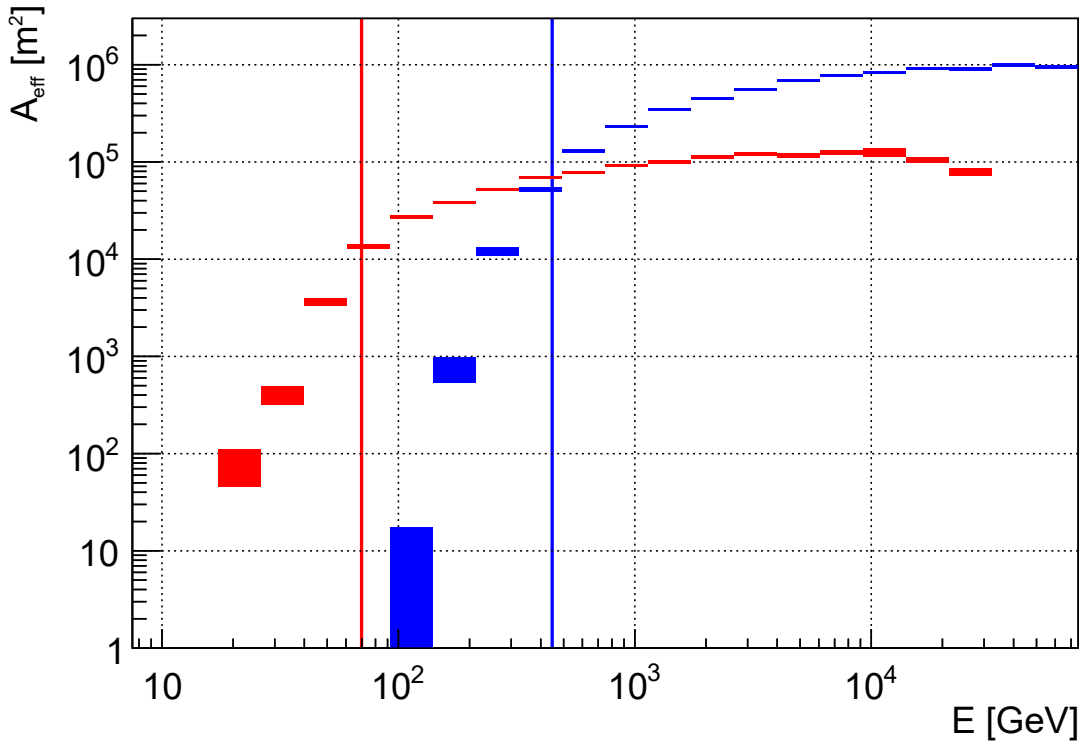
$\Rightarrow$ So far no enhanced variability in other wavelengths

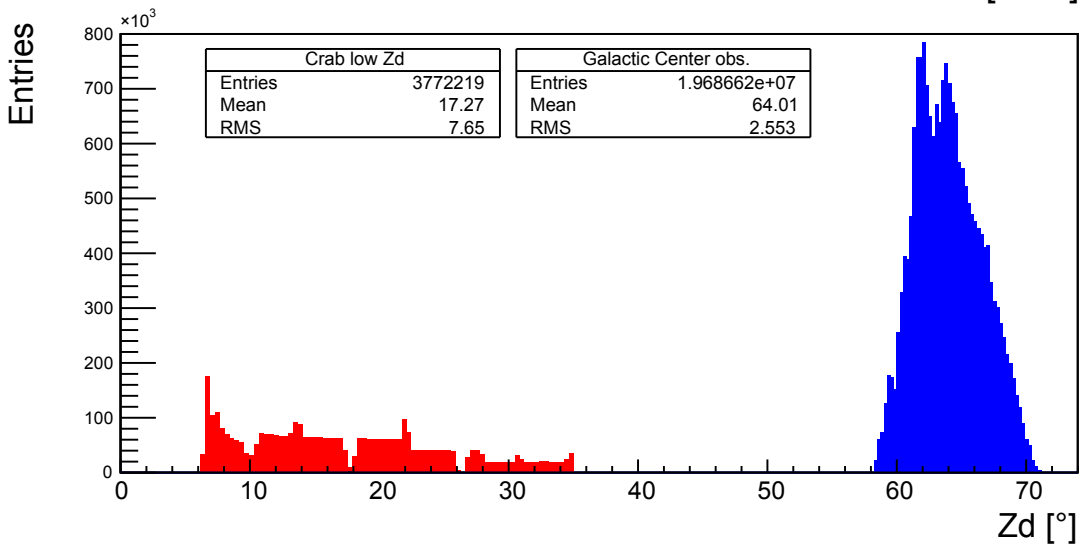
$\Rightarrow$ Monitoring of SgrA* with MAGIC at high zenith angles

$\Rightarrow$ Observations in 2012, 2013, 2014 and 2015 ($\sim$ 65h very good quality)

Observability of the Galactic Center

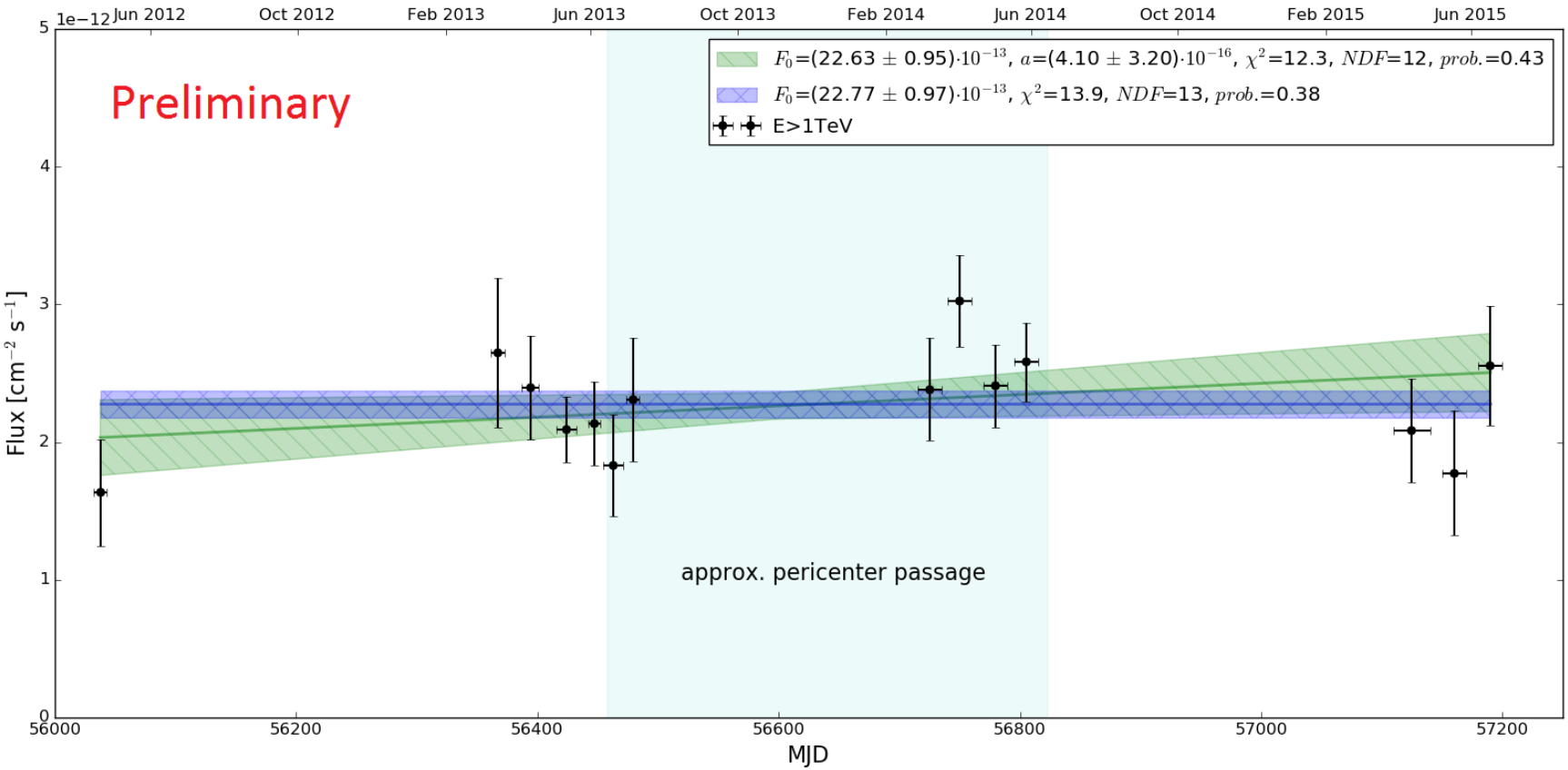
- Culmination at ~58° zenith distance
- Observation at large zenith distance (58° – 70°) with all advantages and disadvantages (light pool size vs. light dilution, enhanced absorption ...)
- Energy threshold increase by factor of the order 10
- Effective collection area increasing by about the same factor
- Good, because in case of hadronic acceleration/diffusion scenarios fastest reaction expected in multi TeV regime (D. R. Ballantyne, M. Schumann, B. Ford, 2011)





Light curve: any observable effect of the G2 flyby?

- MAGIC light curve for the central point-like (SgrA*) source: $E > 2$ TeV, $E > 10$ TeV
- Integration radius 0.14° around SgrA*
- Only very good quality 2012/13/14/15 data (~62h)
- Flux compatible with constant in all energy bands
- Linear fit does not show significant improvement of χ^2
- Also no reports about unusual flux variability in other wavebands



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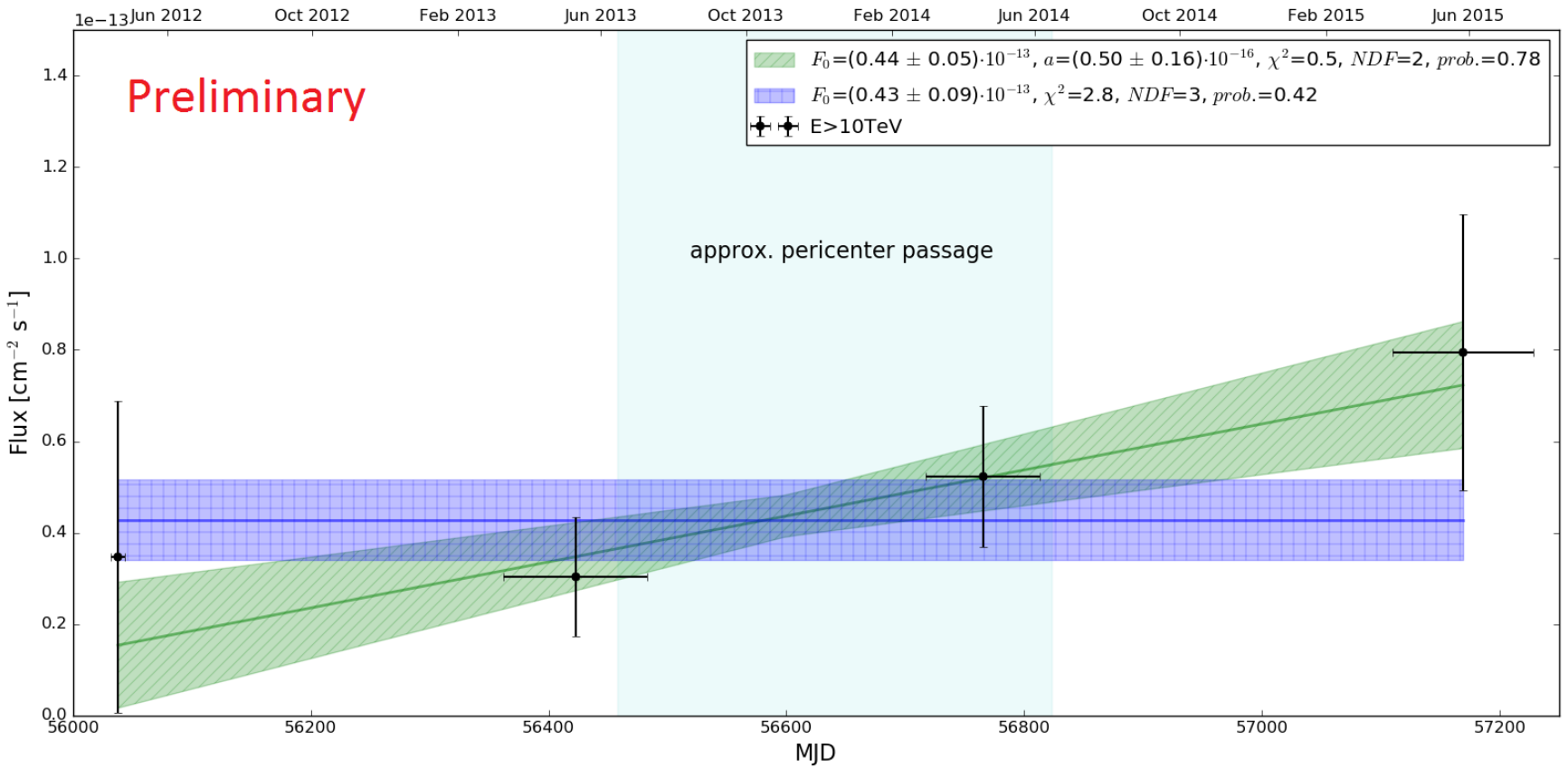
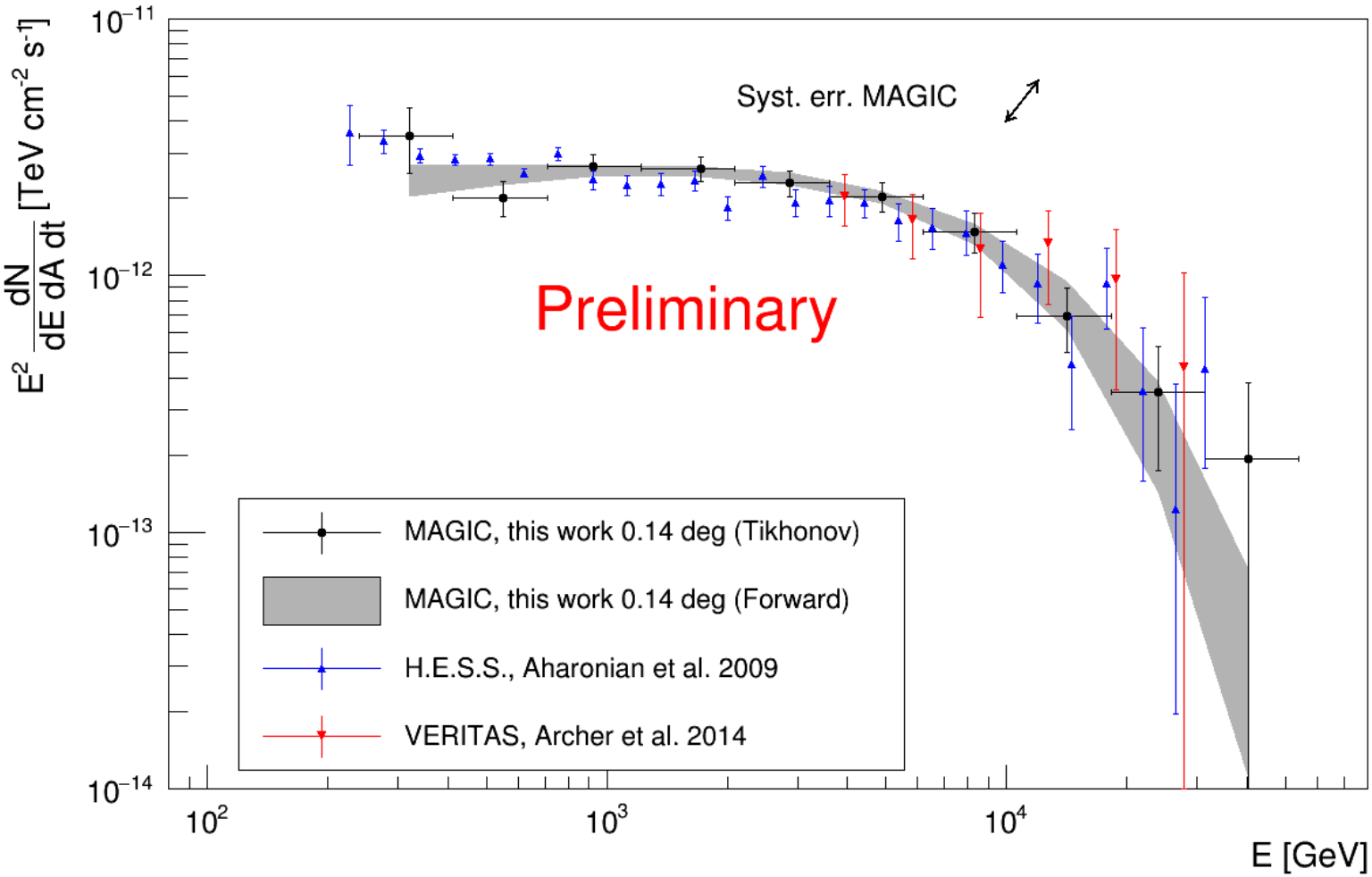


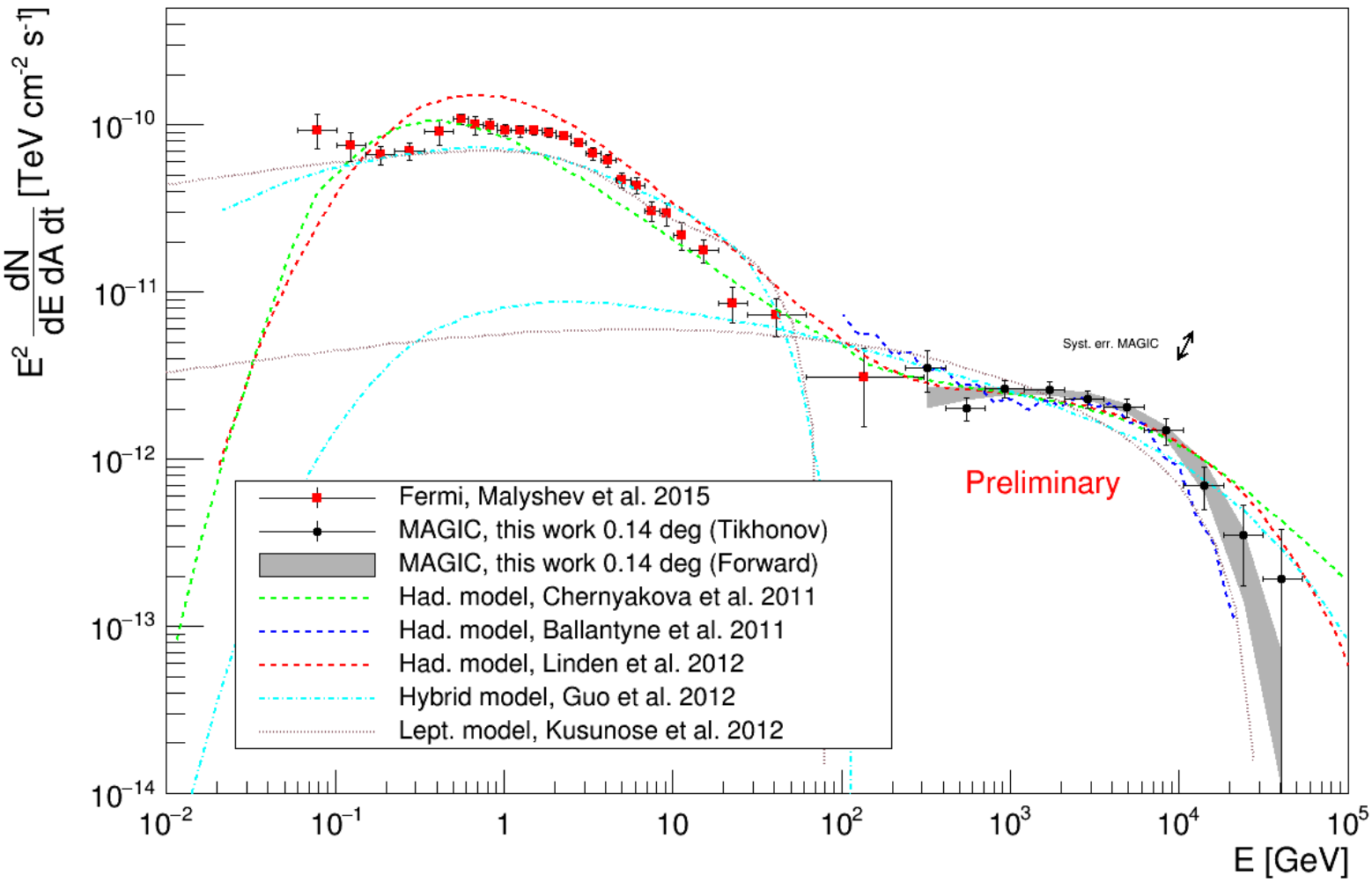
Spectral Energy Density (SED) of SgrA*

- MAGIC SED compared to other previous measurements
- Integration radius 0.14° around SgrA*, ~62h of very good quality 2012/13/14/15 data
- Power law with exponential cutoff fit (forward folding):

$$\frac{dF}{dE} = (7.92 \pm 0.98)\,\mathrm{cm^{-2}s^{-1}TeV^{-1}} \left(\frac{E}{2\,\mathrm{TeV}}\right)^{(-1.86\pm0.13)} \exp -\frac{E}{(8.49\pm2.89)\,\mathrm{TeV}}$$



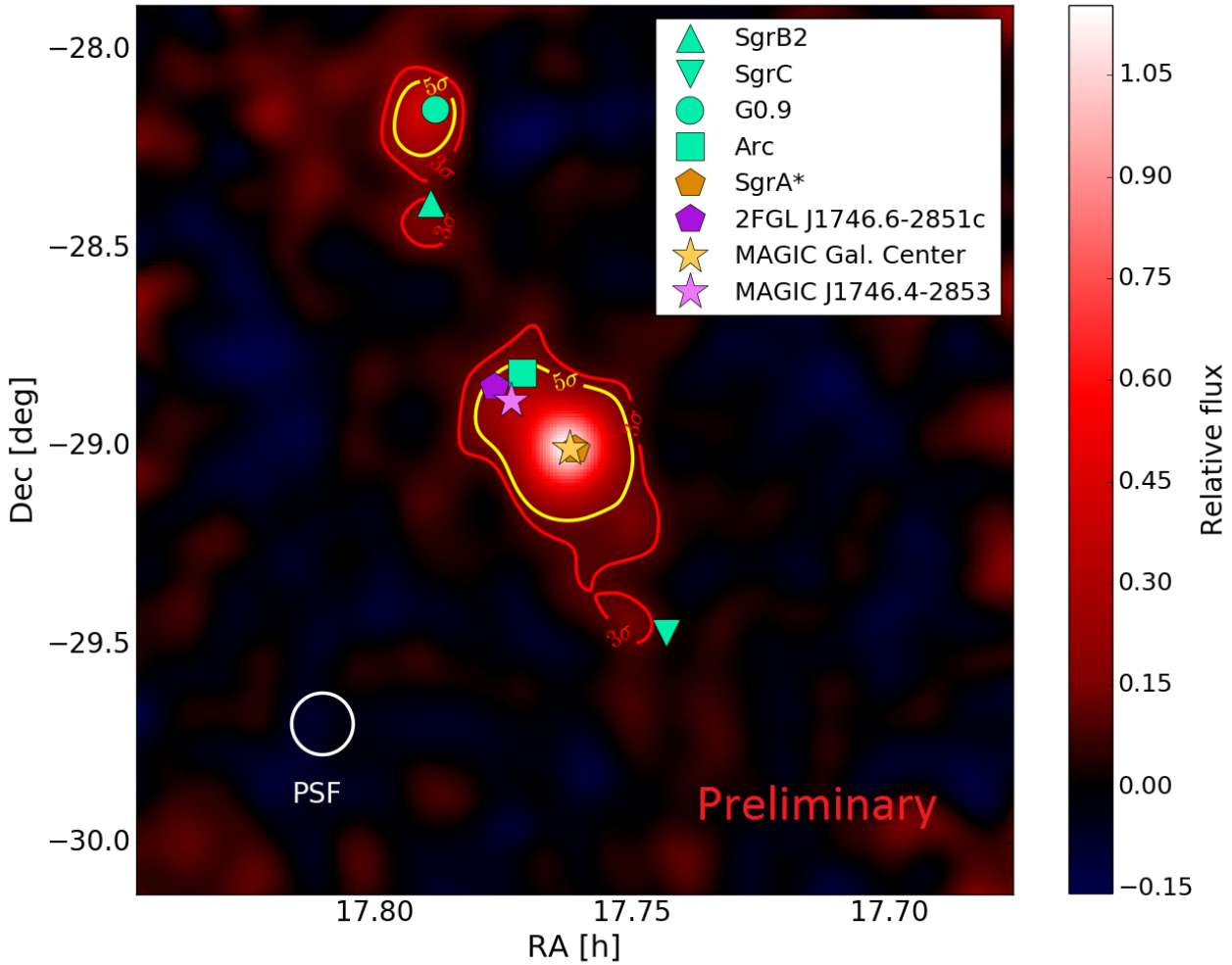
Adding 2015 Fermi data and comparing to models



- peculiar 2-bump structure – none-trivial for modeling
- hadronic scenarios are exploiting morphology (target) and time variability (source)
- leptonic models have problems explaining the spectral shape with single source
- the available data does not yet allow discrimination of models

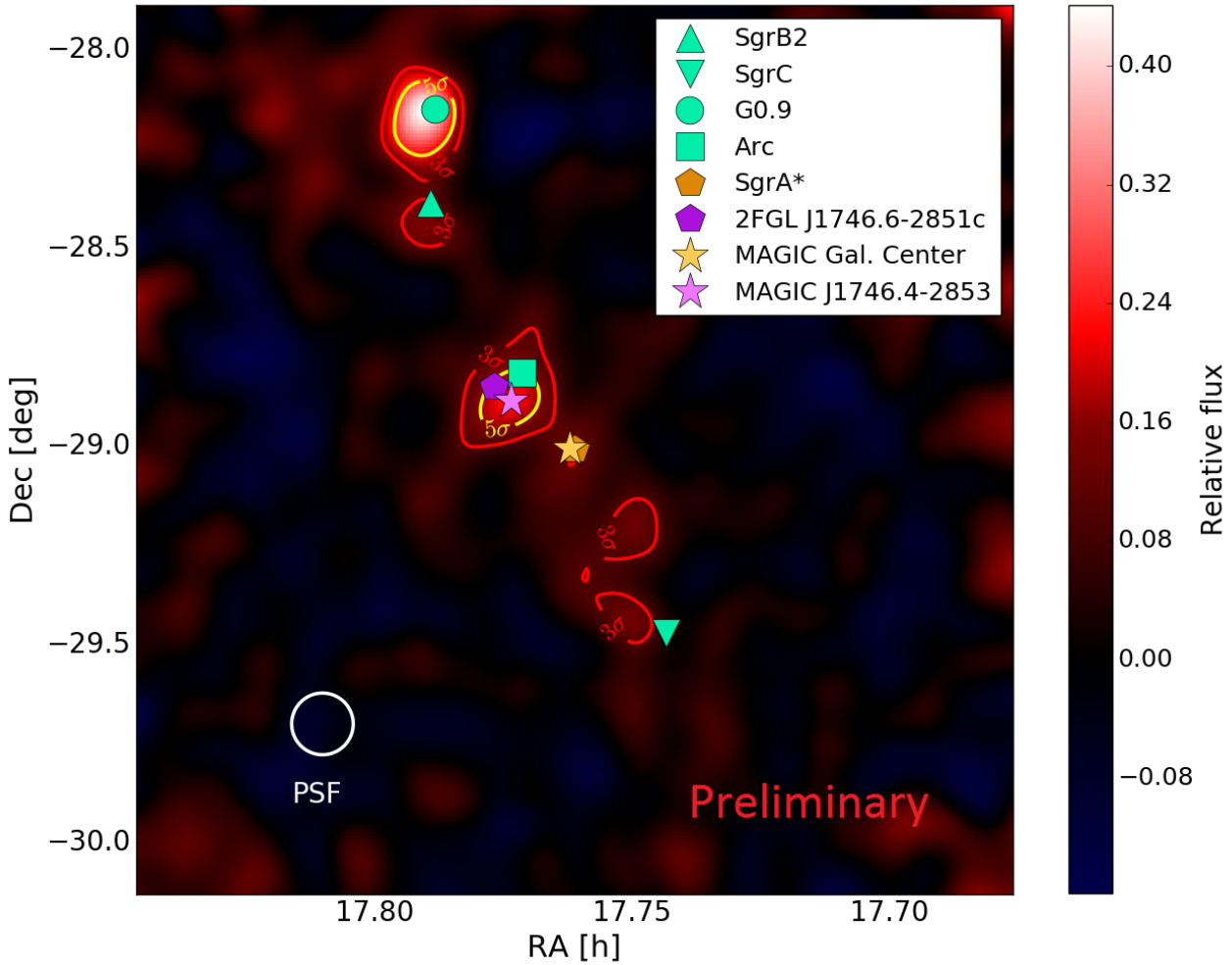
Sky map (~65h) 2012/13/14/15 ($E \gtrsim 1\,\mathrm{TeV}$)

- 2.25×2.25 deg FoV, Galactic Plane from bottom right to top left
- excess in units of background $(N_{on} - N_{off})/N_{off}$ with TS significance contours
- strong point-like contributions from the locations of SgrA* and G0.9+0.1



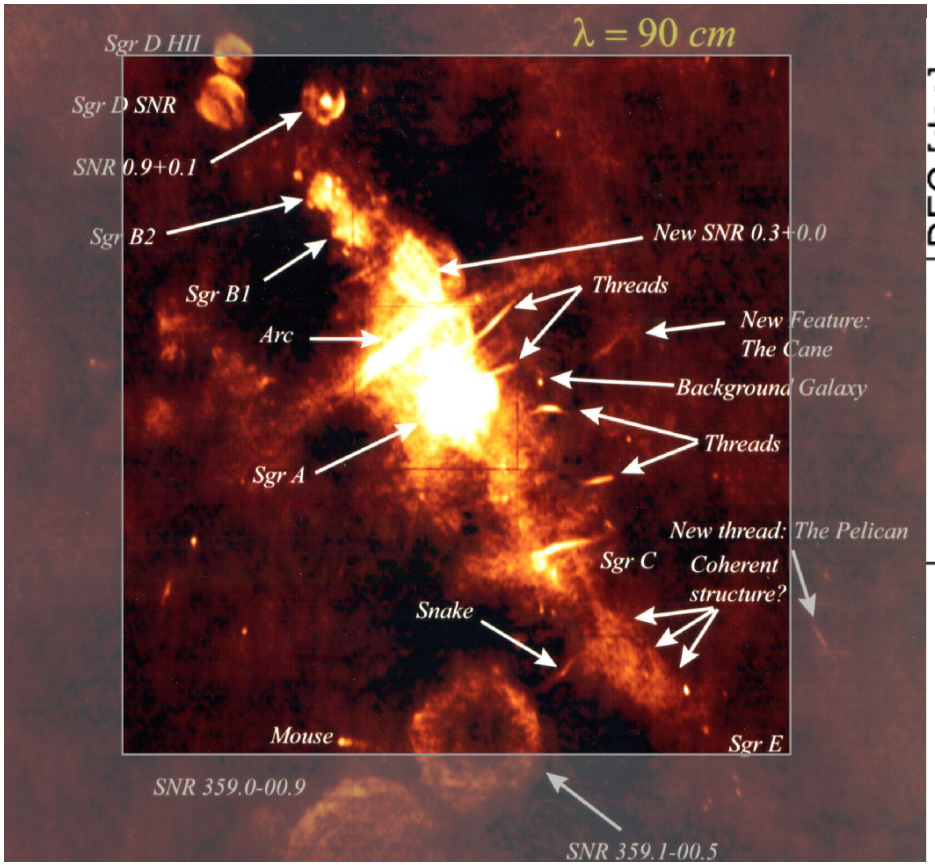
Sky map (~65h) 2012/13/14/15 ($E \gtrsim 1\,\mathrm{TeV}$)

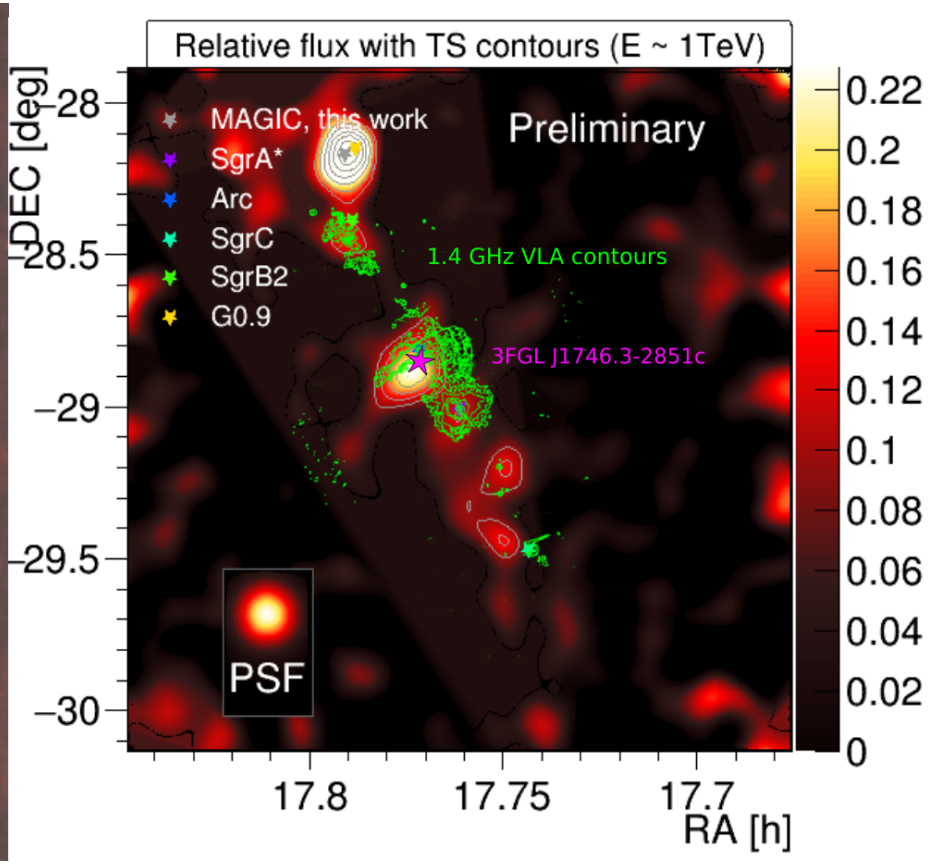
- point source model fitted and subtracted from SgrA* location
- 2.25×2.25 deg FoV, Galactic Plane from bottom right to top left
- excess in units of background $(N_{on} - N_{off})/N_{off}$ with TS significance contours
- New source MAGIC J1746.4-2853
- possible coincidence with 2FGL J1746.6-2851c, HESS J1746-285 and VER J1746-289



Origin of the extended emission

- good correlation between 90 cm radio image and TeV skymap ($E \gtrsim 1\,\mathrm{TeV}$)
- G0.9 is known TeV source (Aharonian et al., 2005)
- detected significant TeV gamma-ray excess apparently coincident with the radio Arc
- MAGIC source is coincident with the Fermi source 3FGL J1746.3-2851c
- Bremsstrahlung from cosmic electrons interacting with MCs? (Yusef-Zadeh et al., 2013)





radio image: N. E. Kassim, D. S. Briggs, T. J. W. Lazio, T. N. LaRosa, J. Imamura (NRL/RSD)

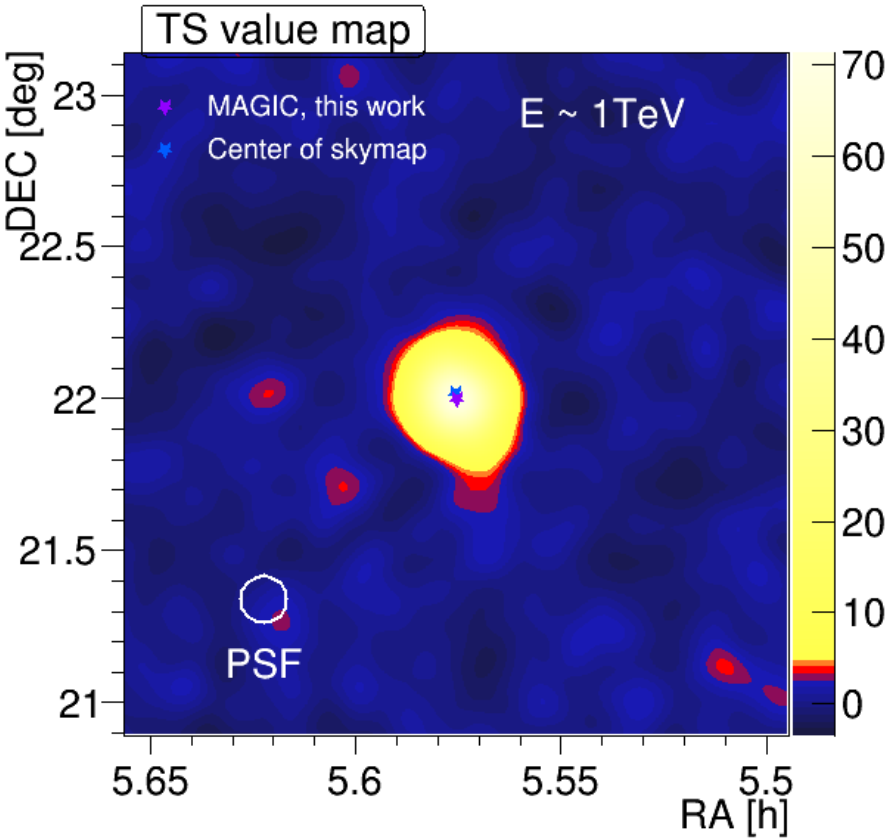
Conclusions

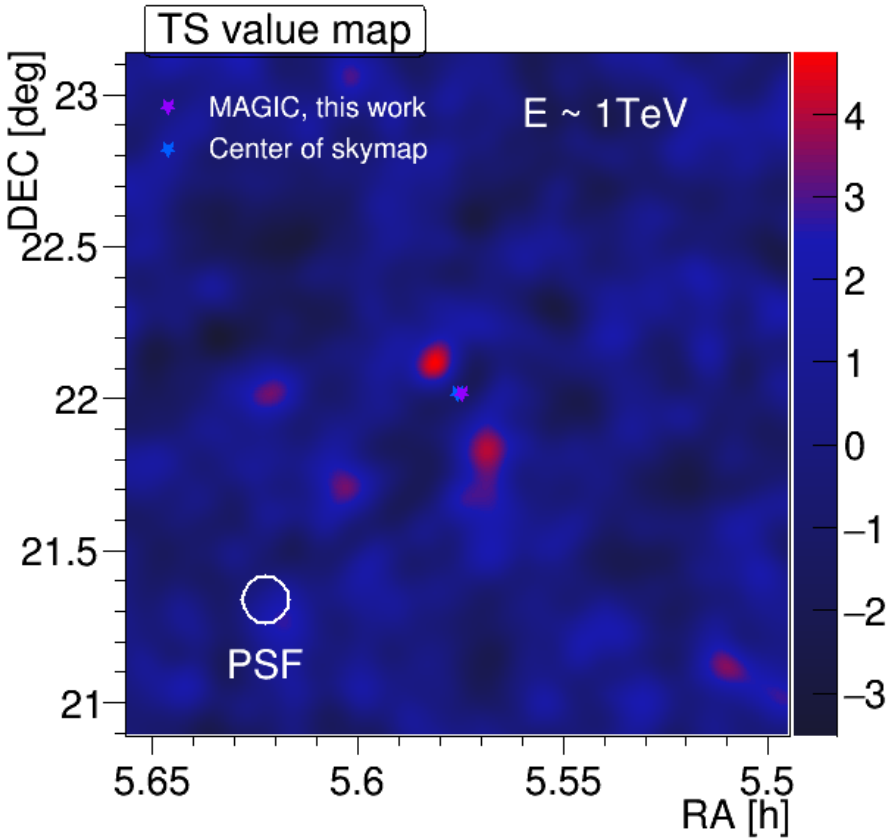
- Large Zd ~60-70° observation technique with MAGIC very successful!
- SED over more than 2 orders of magnitude with only 62h of data.
- No variability in the TeV regime during the closest encounter of the GC with the G2 gas cloud
  - ⇒ Maybe the gas did not reach the accretion zone yet?
  - ⇒ Or the accretion is radiation inefficient?
  - ⇒ Or the gas cloud is very compact (eg. star with stellar wind)?
    - Seems to be the case, because the cloud is still intact after passing the pericentre arXiv:1410.8731).
- New TeV source: the GC radio Arc – source type still unknown, could be PWN, CR-MC interaction or SNR shell interacting with magnetic structure of the Arc
- Very complex and interesting region now being actively studied by MAGIC, H.E.S.S. and VERITAS
- Stay tuned!

Thanks for your attention!

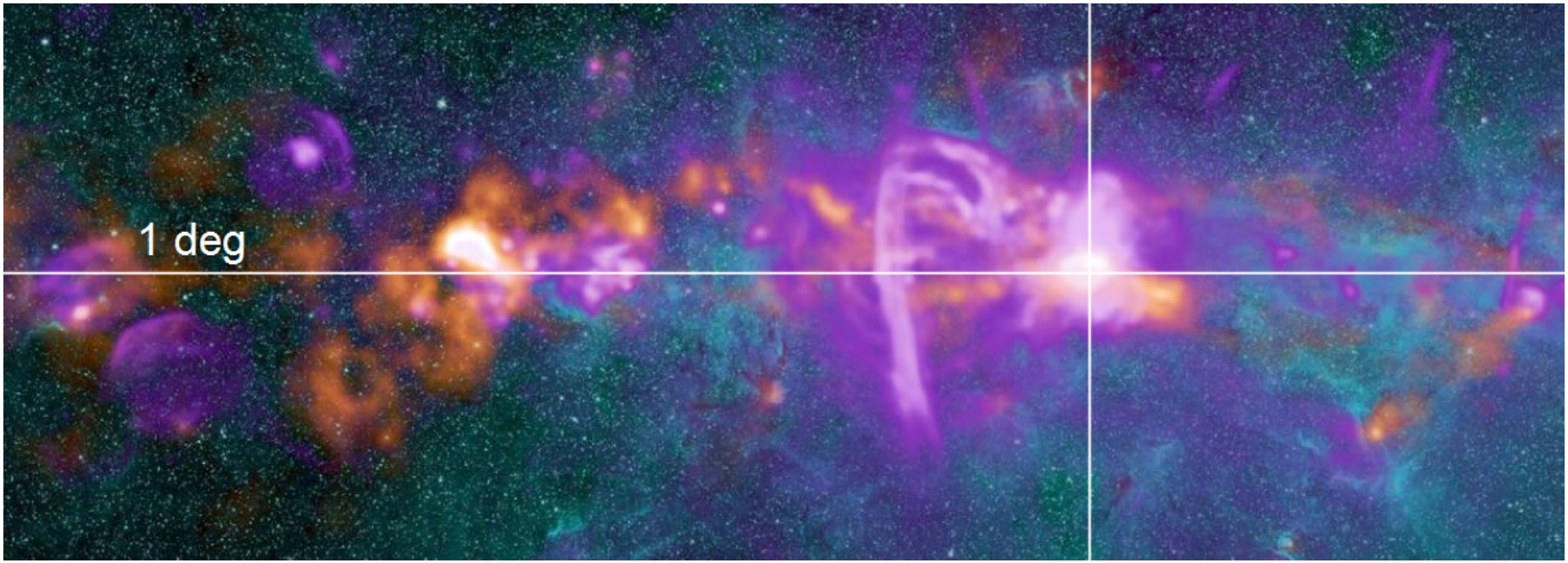
Backup

PSF Model subtracted from Crab Nebula sky map





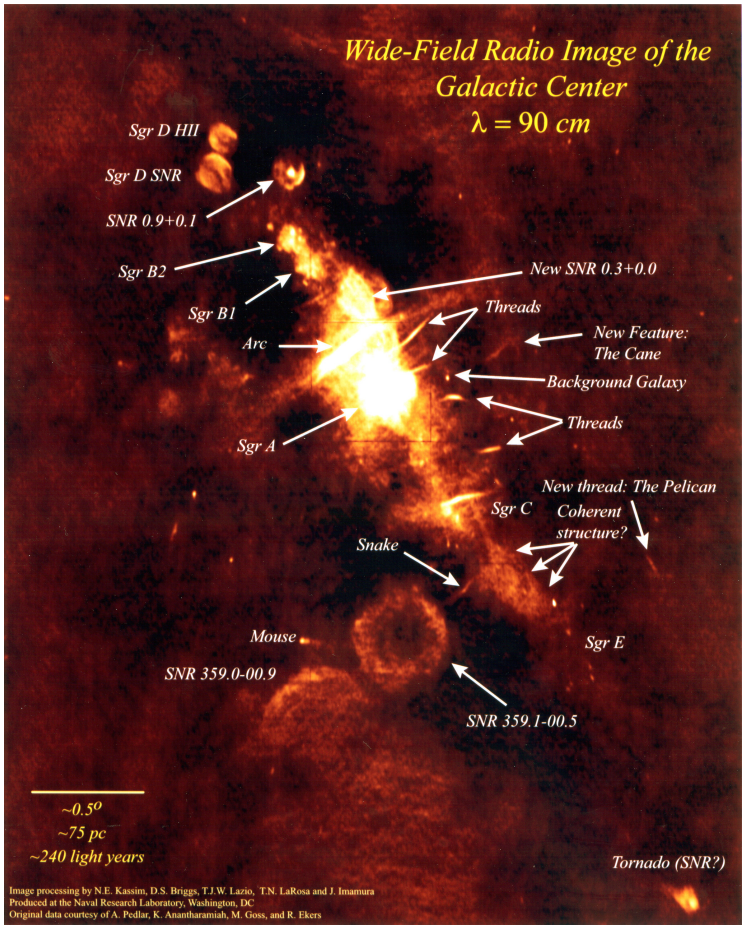
GC region in 20cm, 1.1mm, IR



- VLA (20cm): H II regions that are illuminated by hot, massive stars, supernova remnants, and synchrotron emission
- Caltech Submillimeter Observatory (1.1mm): cold (20-30 K) dust associated with molecular gas
- Spitzer (IR): primarily emission from stars and from polycyclic aromatic hydrocarbons

image source: http://images.nrao.edu

Radio sources SgrA and SgrA*



- bright point-like radio source
- at the center of SgrA-West (Mini-Spiral)
- at the edge of SNR SgrA-East
- thought to be SMBH
- from stelar motions: $\approx 4 \cdot 10^6\ M_\odot$

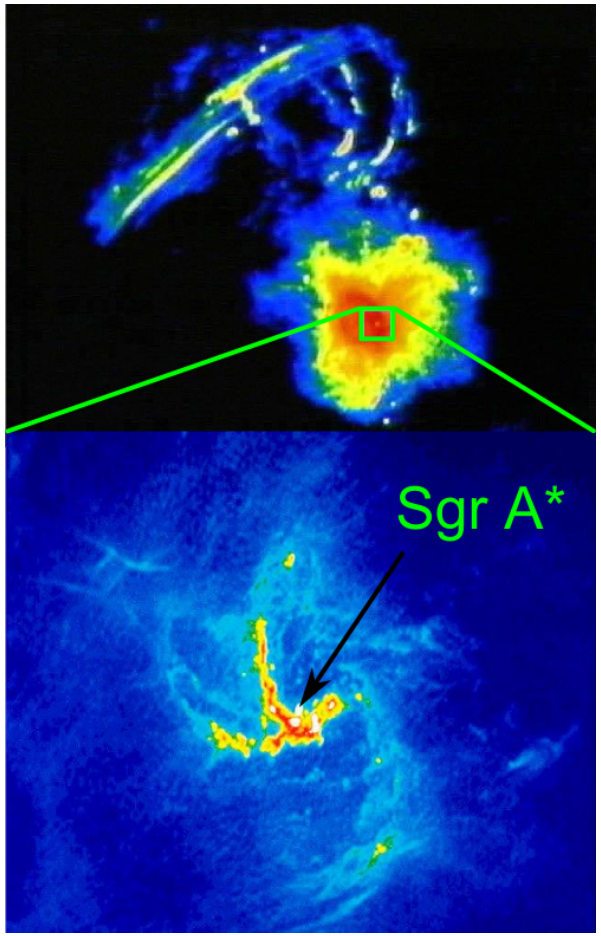
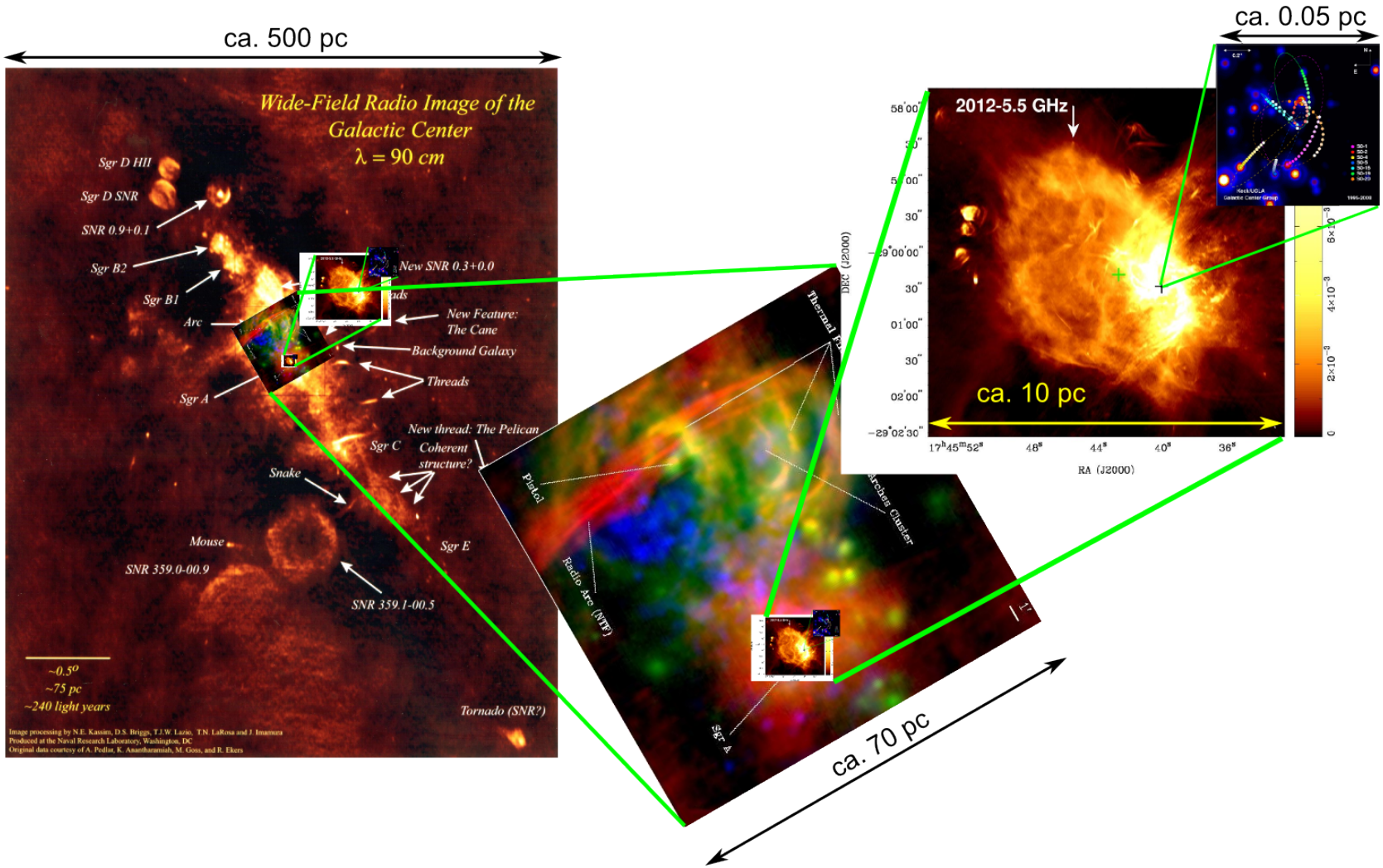


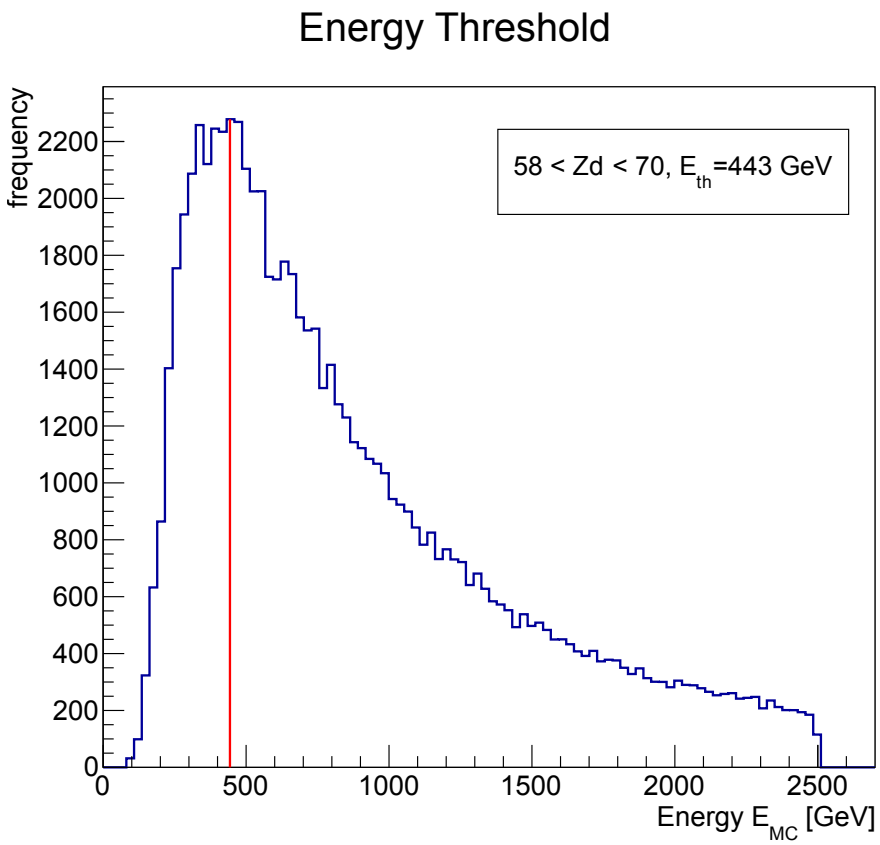
image source (left): N. E. Kassim, D. S. Briggs, T. J. W. Lazio, T. N. LaRosa, J. Imamura (NRL/RSD)
image source (right): astro.ucla.edu

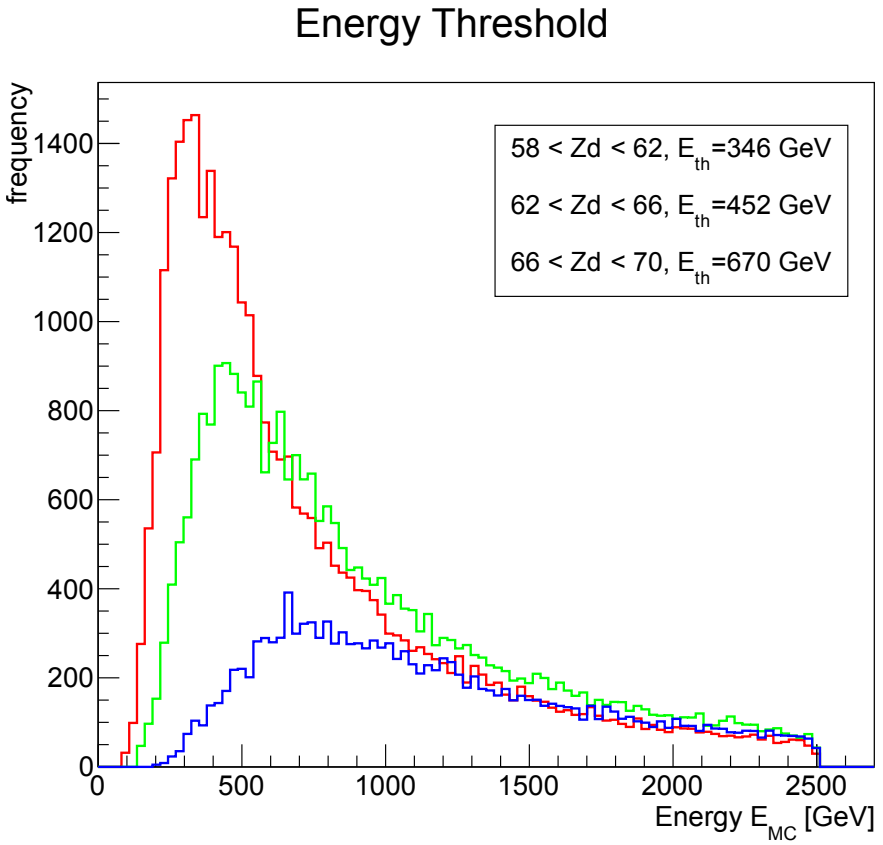


- few 10 OB stars confined inside the central arc-sec around SgrA*
- star S2 periastron: 120 AU, period: 15.6 y

refer to for example: Ghez, A. M., et al. The Astrophysical Journal 509.2 (1998): 678.

MAGIC performance (energy threshold)





For a Crab-like spectral index!